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Characterising the use of urban space: a geochemical case study from *Calleva Atrebatum* (Silchester, Hampshire, UK) Insula IX during the late first/early second century AD

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ABSTRACT

The geochemical analysis of soil samples from the Roman town of *Calleva Atrebatum* (Silchester, Hampshire, UK) has been undertaken in order to enhance our understanding of urban occupation during the late first/early second century AD. Samples taken from a variety of occupation deposits within several, contemporary timber buildings, including associated hearths, have been analysed using laboratory-based x-ray fluorescence for a suite of elements (Cu, Zn, Pb, Sr, P and Ca). The patterns of elemental enrichment seen across the site have allowed us to compare and contrast the buildings that were occupied during this time in an attempt to distinguish different uses, such as between domestic and work-space. Two of the buildings stand out as having high concentrations of elements which suggest that they were dirtier work spaces, whilst other buildings appear to be have lower chemical loadings suggesting they were cleaner.

1. Introduction

Identifying the functions of the internal spaces of Roman domestic buildings is fraught with difficulties. While reception rooms may be identified by the presence of mosaics and cooking areas or kitchens by the presence of hearths, often in close proximity to a latrine, as in Pompeii, characterising the use of spaces for which there are no identifying features other than, perhaps, the nature of the floor and wall decoration, is very difficult. Fire events can be helpful, for example, in the identification of 'shop' assemblages, as for example in Colchester (Hull, 1958, 152–8; 198–202), but the belief that a destructive event, such as of Herculaneum and Pompeii by the eruption of Vesuvius of AD 79, can necessarily preserve evidence that can lead us to interpret the use of buildings or individual rooms, has been convincingly challenged (Allison, 2004). For the vast mass of Roman buildings whose remains do not survive above foundation or floor level the task is even harder than for buildings whose superstructure is, in part at least, intact. Finds, where they occur, may be more an indication of rubbish deposited subsequent to abandonment or destruction than of the remains of material in use at the time of the latest occupation. Floor surfaces are typically of hard materials, easily swept clean, such as mortar, *opus signinum*, stone slabs, tessellation, etc. However, when the buildings are of timber, there is a higher incidence of soft and absorbent floorings, such as beaten earth, clay, plaster, etc, which may trap elemental and microscopic traces indicative of their use.

Wood was widely used in building in the north–western provinces of the Roman Empire in the 1st and early 2nd centuries AD and, in both military and urban contexts, it was the dominant material, except in the construction of certain public buildings, such as baths, or high status, private constructions. While there has been considerable success using archaeological excavation in distinguishing between the different components of a military fort – barracks, granaries, headquarters buildings, etc – and the use of space within them, determining the use of space in the contemporaneous urban context has proved more difficult. Timber buildings are rarely sufficiently well preserved that complete or near-complete plans have been recovered and their remains are often obscured or partly destroyed by superimposed building in masonry, either in the Roman period or later. In Britain well preserved remains of early Roman timber buildings in urban contexts have been found, particularly in London, in the context of recent developments, which have necessitated the destruction of the entire, surviving archaeological record through the careful excavation and

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recording of the remains. Examples of such buildings in London include those recorded since the early 1970s at Leadenhall, Newgate Street, Watling Court and 1 Poultry (Perring et al., 1991; Milne and Wardle, 1993; Hill and Rowsome, 2011). Approaches to the study of such buildings had been pioneered by Frere's excavations in Verulamium (St Albans) between 1955 and 1961, notably in Insula XIV. These had revealed the extensive remains of an early street-side development of timber-built shops-cum-workshops as well as the timber predecessors of some town houses (Frere, 1972, 1983). Typically, the floors of these buildings were of clay, earth and gravel, more rarely of mortar or *opus signinum*, but, other than their plans, the principal distinguishing features of individual rooms were the presence or absence of hearths and ovens.

Excavation of a series of well preserved, early Roman timber buildings in Insula IX, in the Roman town of *Calleva Atrebatum*, Silchester (Hampshire, UK) (Fig. 1), offered the possibility of addressing this deficiency using systematic soil geochemical analysis of floor surfaces to assess how far it might be possible to differentiate between the individual buildings and the rooms within them. This paper builds on earlier study of some of the hearths associated with these buildings (Cook et al., 2010). Previous geochemical work on the masonry buildings which succeeded and directly overlaid ERTB 1 to 3 in the later 2nd and 3rd centuries had identified the working of gold, silver and copper alloy (Cook et al., 2005).

The timber buildings in question extend across a large area (3000 m^2) in the north–eastern part of the Insula and are dated to the late 1st/early 2nd century AD (Period 2 in the excavation sequence). They are separated by a gravelled area into two groups, whose orientations are diagonal to the Roman street grid, which is otherwise aligned north–south/east–west (Fig. 2). The northern group consists of a row of three buildings: a seven-roomed rectangular house with a fronting corridor or verandah (Early Roman Timber Building 2 (ERTB 2)), which is sandwiched between a circular building (ERTB 3) to the south–west and a building, originally

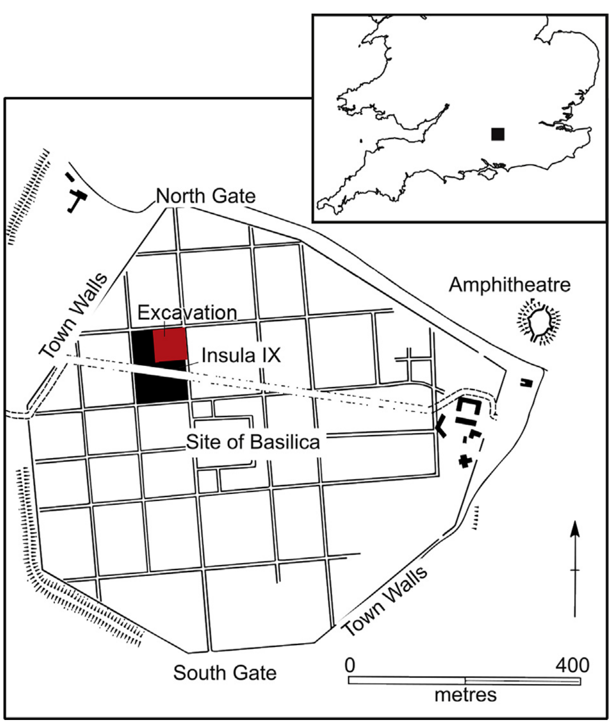

Fig. 1. Location of the excavations within the walls of the Roman town of *Calleva Atrebatum* (Silchester, Hants).

of two rooms and of trapezoidal plan, the latter seemingly determined by the proximity of the east–west street (ERTB 1). For the most part the buildings are floored with yellow clay, though the small Room 1 of ERTB 1 was floored with *opus signinum*, a material which is characterised by inclusions of crushed red pottery or ceramic building material with a chalk/lime based mortar. In addition to the materials used for floor surfacing, some of the buildings contained the remains of hearths, two of ceramic tile in ERTB 1, and one evidenced by a circular patch of burnt clay and tile in the centre of the circular building (ERTB 3). Although patches of burnt clay were identified in ERTB 2, there were no clearly defined hearth structures that compared with those in the two neighbouring buildings. This contrast in the provision of hearths, along with the number and disposition of rooms, has led to an interpretation which sets the central building apart as a higher status ‘town house’, supported by the buildings on either side acting as kitchens and/or the dwellings of lower-status inhabitants, perhaps the household's slaves. Certain features of the circular building suggested an alternative or complementary function as a shrine (Clarke et al., 2007).

To the south of the gravelled area lay a second group of four rectangular timber buildings (ERTB 5–8), one of which was only partly contained within the trench. One of its rooms was floored with *opus signinum*, the remainder, as was the case with the other three buildings, with clay. ERTB 8 fronts on to the north–south street with a stepped façade (Fig. 2). Clay-floored, it included a substantial tiled hearth in the centre of the building. Aligned with it and abutting its western end is a second, clay-floored timber building (ERTB 7), also with a central, tiled hearth. A corridor along the north and west sides represents the only internal division of space within the latter building. ERTB 5, also with a central tiled hearth, was less well preserved. Like ERTB 8 it lay adjacent to the north-south street. ERTB 6 comprised several rooms and extended well beyond the southern limit of the excavation. Only one of its rooms, that floored with *opus signinum,* was available for sampling. Attached to one corner of this room was a tile-built furnace (Fig. 2 context numbers 5154/5725).

Soil geochemical data can provide important information on activities within a given area especially when interpretation has been difficult from artefact data alone (e.g Ball and Kelsey, 1992; Lippi, 1988). Initial investigations used phosphate as an archaeological marker of excretion, manuring and bone (Bakkevig, 1980), more recent work has shown a strong correlation between phosphorus and human activity (see for example Middleton et al., 2005; Oonk et al., 2009). Advances in analytical technology have permitted the simultaneous analysis of large suites of elements at lower detection limits (e.g. Entwistle et al., 1998, 2000). However, in many cases the reason for these enhancements is not well understood (e.g. Heron, 2001). Additionally, the mechanism by which particular elements become associated with archaeological features is seldom understood (Wilson et al., 2005), although features such as hearths may be well defined via element enrichment from fuel sources (Mg, Ca, Sr and Pb), while byres and midden areas are defined by high phosphate concentration (eg. Terry et al., 2004). These processes are well understood: manure, urine and bone hydroxyapatite lead to the fixing of phosphate in immobile forms within the soil near where they are produced. The suite of elements: Ca, Sr, Zn and Pb, also appears to be an indicator of human activity on many sites (Linderholm and Lundberg, 1994; Dirix et al., 2013). Despite the inherent problems associated with correlating soil chemistry to human activities, studies such as that by Wilson et al. (2008) have shown that, although elemental composition is affected by post- depositional processes such as leaching and gleying, it is possible to make the link between chemical patterns in anthropogenic sediments and certain human activities (cooking, animal husbandry, industrial or craft work) (Vyncke et al., 2001).

Fig. 2. Plan of buildings relating to occupation during the late first to early second century AD Insula IX Silchester. Context numbers refer to furnace.

2. Analysis and sampling

Samples (a total of 541) were obtained from a variety of undisturbed contexts (Table 1) across the Period 2 time slice; samples were taken during the course of the excavation and taken back to the laboratory for air-drying. Although the complex nature of the archaeology makes the collection of occupation deposits in this urban context necessarily difficult owing to their interdigitated stratigraphy, we have attempted to sample not only archaeological features such as hearths, burnt deposits and extant tile bases or furnaces, but also general floor surfaces and makeups of both gravel and clay.

The material was dried and disaggregated before being passed through a 1 mm sieve, then ground and pressed into pellets with KBr backing for analysis by x-ray fluorescence (XRF) using a Philips PW1480 XRF with Philips X40 analytical software. Analytical quality was determined by running multiple sub-samples and certified reference material was used to check the accuracy of analysis. All the material was clay-loam to sandy loam in character, in many cases with large (of several centimetres in size) flint pebbles. In some cases samples were not analysed where the material was comprised only of flint pebbles. Material collected from the furnace associated with ERTB 6 comprised not only silty packing material but also tiles, which were ground and analysed as for other samples.

Table 1
Contexts sampled relating to Period 2 occupation of Insula IX. 1a. Early Roman Timber Buildings 1 & 2 (ERTB 1&2). 1b. Early Roman Timber Building 3 (ERTB3). 1c. The South East Buildings (Early Roman Timber Buildings 5–8).

	Context number	Description
ERTB1&2	3260	Levelling deposit.
	3263	Floor/levelling deposit.
	3961	Levelling layer.
	4222	Clay spread probably associated with yellow green clay (4160) inside the walls of probable building.
	4231	Occupation deposit excavated within the hearth slot.
	4244	Burnt clay associated with the 3rd phase of hearth (4234).
	4554	Levelling deposit.
	4594	Burnt material spread in patches across gravel (south of room 1 and spreading further north along aisle).
	4754	Gritty silt in between the second and third phases of hearth 4234, perhaps as a levelling between phases.
	4755	Second phase of tiles in hearth 4234.
	4766	Gritty silt in between the first and second tile layer of hearth 4234. Possibly an accumulation of hearth material or levelling phase.
	4767	First tile phase/foundation of hearth 4234.
	4836	Green, yellow clay interior floor surface. Same as (4170) and (4160).
	5848	Clay layer comprising the house floor associated with hearth 4234.
	5869	Silty layer, which was revealed following the removal of cleaning layer, contains a reasonable amount of CBM and pottery that seems concentrated towards the northern edge.
	5870	Clay layer – probable floor layer – surrounding CBM beam foundation
	5872	Re-deposited sandy clay spread. Probable interior floor surface extending from the north east main building into the extension. Latest phase of flooring associated with the hearth construction.
	5880	High status, opus signinum floor surface within the extension to the main north east house. Possibly a shop front or a private room attached to the house.
	5889	High status floor surface within the small addition to the northeast timber house.
	5919	Dark, charcoal-rich layer within the north east building, adjacent to the northern and eastern sides of hearth 4234. Probably associated hearth debris.
	5921	floor surface within the north east building located near to hearth 4234.
	5929	Burnt patch, south of hearth 4234 and likely to be associated with the second or third phase of use.
	5996	Extensive spread of silty sand, possible occupation layer. Cut by [5997] which may represent a bench or work structure laid into the floor.
	6008	Accumulation deposit – one of a number of similar deposits associated with hearth 4234, most likely from hearth sweepings or general hearth function.
	6014	Silty clay floor surface, inclusion of fragments of CBM tiles which are most likely to be floor tiles.
	6028	Clay floor.
	6030	Silty clay floor layer, possibly a working surface in the vicinity of the main hearth.
	6038	Loose, dark brown/grey sandy silt, Possibly a layer of hearth sweepings or general debris associated with hearth 4234.
	6453	Gravel spread.
	6511	Occupation deposit.
	6990	Hearth with mortar bonding, measuring 1.02 m $\times$ 1.02 m consisting of a highly fragmented, square ceramic tile (150 mm $\times$ 150 mm).
ERTB3	3925	Gravel make-up layer.
	3926	Burnt Clay associated with hearth 4407.
	3927	Burnt part of floor surface (4420).
	4081	Demolition dump.
	4420	Latest clay floor of roundhouse (ERTB3).
	5519	Clay deposit within hearth/fill of 4407.
	5520	Layer of burnt silt within hearth/fill of 4407.
	5556	Clay surface of round house 5570.
	6551	Post hole/pit cut containing.
ERTB 5 The "Oyster House"	7477	Clay floor.
ERTB 6	5154	Furnace.
	5652	Hearth sitting on opus signinum floor (5618). Made up of two large blocks of CBM and two medium blocks with a smaller one inside and thinner ones round the periphery (probably broken off from a larger block). The larger blocks have a darker burn marks. A semi-circle is marked onto one block. The whole structure sits lightly on the opus signinum floor and appears quite intact.
	6418	Opus signinum floor.
	6420	Opus signinum floor.
ERTB 7	6952	Clay floor.
ERTB 8	5125	Dump of building material and clay. Possibly the remains of a hearth.
	5690	Hearth.
	5743	Burnt clay area surrounding hearth – possible floor. A charcoal deposit surrounding the hearth suggests possible occupation abandonment and the subsequent use of another hearth in close proximity.
	6265	Charcoal and silt accumulation deposit from extensive occupation and possible metal-working in this area.
	6287	Clay accumulation layer above hearth 5125.
	6317	Hearth tiles, partially exposed within an orange/red clay layer.

3. Results and discussion

In order to make observations based on spatial elemental concentrations each element has been plotted on a scale of multiples of background concentration (Fig. 3). Background material was collected from the three major geological deposits surrounding Calleva, the Bagshot Sands, the London Clay and the Silchester Plateau Gravels (matrix only) and an average baseline concentration determined. The results were then colour coded to allow ease of "hot-spot" identification; these may only be one elevated sample, or more interestingly a cluster of elevated concentrations, single "hot-spots" are difficult to interpret as they may result from

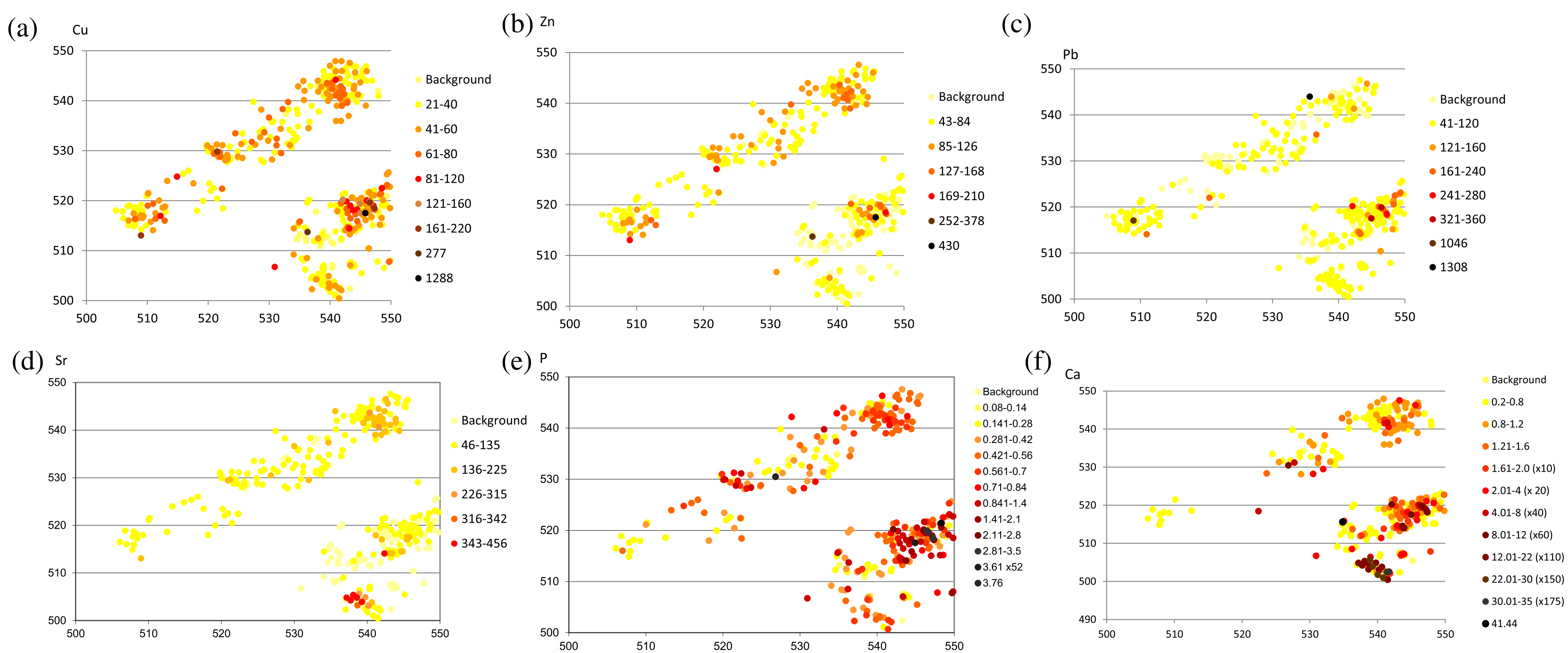

Fig. 3. Elemental concentrations (mg/kg dry weight) found in soil samples from sampled buildings presented as multiples of background concentrations. Bracketed figures indicate multiples of background concentration. Samples are plotted on the site grid using Eastings and Northings. 3a Copper. 3b Zinc. 3c Lead. 3d Strontium. 3e Phosphorus. 3f Calcium.

the presence of a fragment of bone, metal or charcoal, grouping of elevated concentration on the other hand allow spatial comparison within and between buildings.

3.1. Trace metals

For the purposes of this work we were particularly interested in elemental patterns that might indicate metalworking and to this end we focused our analysis on commonly used metals: copper, zinc and lead. As well as helping to define areas of possible metalworking (in conjunction with finds which included slag) around hearths, these elements have been used as general indicators of human activity and have been found in elevated concentrations in areas where vegetables were processed (Da Costa and Kern, 1999) and in and around buildings (Lewis et al., 1993). It is of course important to stress that this work focuses on bulk sample analysis and does not address metal phases present with the deposits, metals may be present as both integrated soil constituents, within mineral lattices, adsorbed to clay or organic surfaces as well as discreet fragments of metal, charcoal, bone and pottery. The bulk analysis of the soils give general trends and patterns which we use in conjunction with the archaeology to help understand the use of space.

3.2. Copper

Fig. 3a shows the concentrations of copper found in contexts associated with Period 2. All samples are above the background average and a copper “hot-spot” is clearly visible centred on ERTB1. The highest concentrations of Cu within ERTB1 are associated with contexts 4836, 4754 and 4594 respectively. Context 4836 is a floor surface within ERTB1 and in the vicinity of hearth 1433/4234, whilst 4754 forms part of an accumulation layer within this hearth. Copper is known to preferentially bind to organic matter (see for example; Alloway, 1990) and the elevated concentrations of Cu seen in association with these hearth deposits may be a result of the accumulation of charcoal and the subsequent binding of Cu to the organic matter present. Hearth 1433 is, however, thought to have had a multi-purpose mode in which some of its use may have been industrial (Clarke et al., 2007). This is a large central hearth and micromorphology samples (see Cook et al., 2010; Banerjea, 2005) from the floor surfaces within ERTB1 show that the deposits surrounding hearth 1433 are comprised of mud-plaster makeups characterized by the distribution of coarse particles, with the coarser components of sand, gravel, pottery and plant remains added as temper or stabiliser in a finer clay matrix. The phytolith assemblage from this floor suggests that it was overlain by rushes and that some low-level cereal-processing may have taken place. The floor of Room 2 (ERTB1) was made of *opus signinum* and may have constituted a shop front or higher status reception room; certainly the concentrations of Cu are generally lower in this area. Copper is found in higher concentrations within samples associated with ERTB1 than ERTB2, with the notable exceptions of a “hotspot” at the SW end of ERTB2 (context 8223: 221 mg/kg Cu), which comprises an organic-rich charcoal dump, and a “hotspot” at the edge of the roundhouse ERTB3 (context 6682) which comprises a charcoal fill from a votive pit (Clarke et al., 2007). Other concentrations of copper, found in samples associated with the round house ERTB 3, are highest in the centre of this building in the vicinity of hearth 4407. These contain significant organic matter which is the likely source of the high concentrations of copper, this maybe a result of the sweeping out of a hearth and its associated charcoal for copper will preferentially bind.

Copper concentrations within ERTB8 among the southern group of buildings are the highest concentrations found in any of the Period 2 samples. They are associated with context 6265, a charcoal and silt accumulation. Context 6265 is part of a group of deposits which surround hearth tiles (6317) and burnt clay (5743). It seems likely, given the extremely high concentrations of Cu (and Zn see below) found in this context (1288 mg/kg Cu), that this area was used for metal-working, suggesting an industrial rather than a domestic purpose for the building (cf Cook et al., 2010, 873–4). The other buildings in this area are markedly different in that the copper concentrations are lower than in ERTB8 with one exception: the “hotspot” associated with ERTB7 context 9841 (277 mg/kg). Context 9841 is a gravel makeup layer which underlies deposits associated with Hearth 4525. ERTB5 and 6 have markedly lower copper concentrations with no “hotspots” and are therefore more likely to have had a domestic function and have been kept cleaner leading to a depletion in elements via the removal of enriched sediments during sweeping.

3.3. Zinc

Zinc concentrations are elevated in the centre of ERTB1 in the vicinity of the central hearth (Fig. 3b). Elevated zinc is associated with samples from contexts 4751 and 4754 which form accumulation layers linked to the large central hearth (1433) (see above, p. 00, for detailed discussion of this hearth). Several authors (e.g. Middleton et al., 2005; Lewis et al., 1993) have found elevated zinc associated with both activity areas and artefact spreads; plant ashes can also contain zinc at levels at least 10 $\times$ sediment values (Wedepohl, 1969). As with copper; zinc concentrations are lower in street-front Room 2 of ERTB1 suggesting that it was cleaner than the back room.

Concentrations are generally lower along the length of ERTB2 with the exception of one “hotspot” associated with context 7223 (208 mg/kg). This context is made up of a deposit of charcoal-rich, occupation material with bone and pottery fragments. Zinc concentrations in ERTB3 (Fig. 3b) show an activity area to the SE of the building with one “hot-spot” concentration specifically associated with context 6682. This is coincident with elevated Cu concentrations in the organic-rich fill of the votive pit (above, p. 00).

Elevated zinc concentrations are also found in the SE of the trench in samples from ERTB8 (430 mg/kg Zn). These belong to a hearth (6265) and the extremely high concentrations of both zinc and copper found in this area suggest this hearth was used for industrial purposes, probably metalworking. This building is noticeably different to the other buildings in the southern group in that metal concentrations, particularly copper and zinc are far higher, indicating that the floor deposits in this building were enriched in meals compared to the others.

ERTB7 contains one “hotspot” of zinc which is again coincident with a copper “hotspot” within context 9841. The interpretation of this “hotspot” is uncertain but may relate to an earlier hearth.

3.4. Lead

The highest concentrations of Pb in ERTB1 (1308 mg/kg; Fig. 3c) are found in association with hearth 1433 which supports the notion of a multi-function, intensively used hearth (see above). Lead is also present in elevated concentrations in ERTB3 (context 5520: silty layer within hearth 4407) at 1046 mg/kg dry weight which is 35 times greater than average background concentrations. This lead hotspot is coincident with both elevated copper and zinc. One other lead “hot-spot” is present associated with context 3925, a gravel make-up layer; both of these hotspots are in the vicinity of the central hearth.

Among the southern group of buildings lead concentrations are noticeably elevated in ERTB8. This recalls the patterns of copper

and zinc concentrations and is centered around hearth 6265. However, the other buildings in this area are distinct from ERTB8 in that the concentrations of lead are barely above background levels (with one exception see below), indicating that activity involving (whether directly or indirectly) lead-bearing materials was confined solely to ERTB8, unlike copper and zinc which show some elevation in ERTB7 and 6. This may reflect the differing sources of the metals and the association of copper and zinc with organic material (plant matter as both flooring and ash) as well as with possible industrial/craft activity. This in turn further strengthens the interpretation that ERTB8 had a much more industrial/work based function than its neighbours. The sole lead “hot-spot” associated with ERTB6 belongs to the group of samples taken from context 5154 – the furnace, without detailed microscopic investigation of this sample we are unable to tell whether this sample contained elevated mineralogical lead or fragments of lead from artefacts.

3.5. *Strontium, calcium and phosphorus*

The concentrations of Sr and P are shown in Fig. 3d and e. Both have been shown to be associated with human activity, particularly animal husbandry and food preparation (Middleton et al., 2005; Oonk et al., 2009). Phosphorus is present in all living things and is therefore a strong indicator of the processing and/or storage of organic materials (food), waste disposal, burning of organic matter or the disposal of human and animal faeces. Strontium is present in bone and can be an indicator of meat preparation (Wilson et al., 2008). Middleton et al. (2005) showed that calcium can be associated with food preparation, as well as with the presence of ash, but at Silchester Insula IX there are also some specific floor deposits (made up of crushed shells and *opus signinum*) which contain high calcium and therefore high Sr.

Strontium is slightly elevated above background in ERTB1 whilst Sr loadings in ERTB2 appear depleted with concentrations at background or at twice background concentrations. Using strontium concentrations it is again possible to distinguish between Room 2 and the enriched elemental loadings Room 1 of ERTB1.

Phosphorus (phosphate) is elevated well above (at least 4 $\times$) background concentrations in both ERTB1 and 2 although the samples collected from contexts associated with ERTB1 are generally higher in P than those from ERTB2, perhaps also an indication of a cleaner environment in ERTB2. The archaeology also supports a more domestic function for ERTB2: although only half the ground plan of the building is preserved, it has been suggested that the surviving remains represent a residential town-house, initially articulated around a central reception room (Clarke et al., 2007). The evidence suggests only domestic functions, but with the absence of evidence for a kitchen which suggests that function was probably provided by one or both of the adjacent buildings, ERTB1 and ERTB3. High concentrations of P are found at the southern end of ERTB2 coincident with both a zinc and copper hotspot, and associated with a dump of charcoal-rich occupation material which also contained significant bone, the likely source of the high phosphorus.

Phosphorus is found in the highest concentrations in samples from ERTB8, a building which, as previously discussed, contains elevated concentrations of trace metals including copper and zinc. The presence of these high P values highlights the elevated metal loadings present in this space and lends weight to the hypothesis that this was indeed a dedicated work space rather than a multi-function mix of domestic and light craft activities. Indeed the very high concentrations of P found here also serve to differentiate this building from ERTB1 with its presumed, more multi-functional purpose.

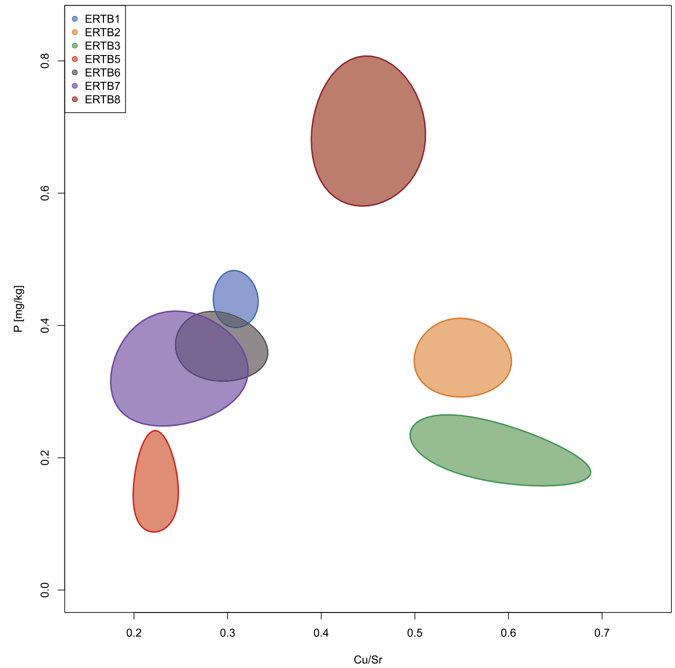

Fig. 4. Confidence (95%) regions for the mean elemental concentrations Period 2 buildings Insula IX, Silchester.

Strontium, P and Ca (Fig. 3f) are all present at low concentrations with no “hotspots” within ERTB3. Sr is present at concentrations equivalent to average background values, P is present at 3 $\times$ background and Ca at around 10 $\times$ background. This distribution of major elements is in sharp contrast to ERTB1 and 2 which both show highly elevated P concentrations and several “hotspots”, notably for Ca in association with hearths. It is possible then that ERTB3 was kept cleaner than either ERTB1 or 2 with the floors regularly swept, thus depleting the concentrations of elements. The presence of buried remains, animal and neonate, cremated animal bone and vessels placed as foundation deposits supports the suggestion of a “special” function for this building (Clarke et al., 2007).

A distinct activity area among the southern group of buildings is represented by elevated concentrations of Sr, P and Ca from an *opus signinum* floor within ERTB6 (contexts 6420, 6418) (Fig. 3 d e and f). This relatively high status floor surface may be expected to have been swept clean and, indeed, the trace elemental concentrations are correspondingly low. The high Sr and Ca are a result of the chemistry of the calcium carbonate-rich (lime mortar) composition of the *opus signinum*. The elemental concentrations found in samples from the brick-lined furnace (context 5154) attached to ERTB6 are not especially high with the exception of one sample which contains above average calcium concentrations and may thus represent a particularly ash-rich sample. This suggests that the furnace had a domestic (water heating perhaps) rather than a craft or industrial function.

Although calcium concentrations are all above background levels within ERTB 1 and 2 (Fig. 3f), two “hotspots” may be observed; one coincident with hearth 1433 in ERTB1 and the other in ERTB2 contexts 3260, which is a levelling deposit located within the central Room 4, and 4594 which comprises burnt material spread across the gravel floor and also contains elevated Cu concentrations. These Ca “hotspots” may represent hearth sweepings, as previous work (see for example Middleton et al., 2005; Terry et al., 2004; Linderholm and Lundberg, 1994) has shown that elevated Ca levels are associated with human activity areas and hearths.

The concentration of Ca is also elevated in the southern building ERTB8 context 6317, possibly a result of calcium carbonate packing-material in hearth 6265. The use of bone or the residues of burning organic matter may also explain the presence of high Ca concentrations. Indeed in samples from Çatalhöyük enrichment of Ca was found associated with the burning of wood/plant material, animal penning and food preparation (Middleton et al., 2005).

4. Analysis of results

The complex nature and inherent difficulties of sampling an extensive and gravelly site mean that there are necessarily some bias in the results, some buildings were sampled more extensively than others, some had more hearth areas and the concentrations may appear correspondingly high. In order to make a more straightforward comparison between the buildings and to interrogate the data a little further we compared the average concentrations of elements for each building and looked for corresponding relationships.

Since the measured concentration ranges show a lot of overlap between buildings, we used techniques from multivariate statistics to analyse the statistical differences between buildings. The main aspect of this analysis is to assess the uncertainties associated with estimating of the mean elemental concentrations from the given samples. The results of our analysis, explained in more detail below, are shown in Fig. 4. The coloured patches in the figure represent the range of uncertainties for joint estimates of the means of phosphorus concentration (on the vertical axis) and the ratio of copper to strontium concentrations (on the horizontal axis), grouped by building. In the figure, geometric separation of the confidence regions can be interpreted as statistical differences between concentrations of buildings. Three groups of buildings are clearly distinct in theplot: ERTB2 and ERTB3 have high Cu/Sr ratio but low phosphorus concentrations. ERTB8 has high phosphorus concentration, and medium Cu/Sr ratio. Finally, ERTB1, ERTB6, ERTB7 and ERTB5 have low Cu/Sr ratio and low Phosphorus concentrations. This process results in a clear distinction between ERTB8 and the other buildings, highlighting the difference between this building and the other enriched building ERTB1, ERTB8 having the higher concentrations of P of the two and more likely to have had a dedicated workspace function as opposed to the proposed multi-functional kitchen/workspace use of ERTB1. Of the other buildings ERTB5, 6 and 7 belong to a group of buildings that are probably more domestic and less workspace in function.

We now describe the procedure used to construct Fig. 4 in more detail: First, from inspecting pair scatter plots of the elemental concentrations for Cu, Zn, Pb, Sr, and P, it is obvious that the concentrations themselves are far from being normal distributed whereas the logarithms of the concentrations (ignoring units) are much closer to being pairwise normally distributed. For this reason, we performed the analysis on the logarithms of the concentrations rather than on the concentrations themselves. At this stage we also removed a small number of outliers (one from ERTB1, ERTB3 and ERTB7 each, and two from ERTB8). Specifically these are the samples associated with hearth material e.g contexts 5520 (highPb), 7477 (low Pb), 8640 (high Sr) and 6265 (high Cu).

Assuming that the logarithmic concentrations are normally distributed, standard methods can be used to determine five-dimensional, ellipsoidal confidence regions for the joint mean of the logarithmic concentrations. To allow easy interpretation and visualisation, we want to project the data to a two-dimensional space, and to choose a pair of variables such that the differences in group means show as clearly as possible. Principal component analysis (PCA) can be used to choose such coordinates in a systematic way, but the resulting coordinates, being linear combinations of the logarithms of all five elemental concentrations, are difficult to interpret in an archaeological context. Thus, we chose coordinates which only approximate the first two principal components, namely (the logarithms of) the ratio of copper to strontium concentrations (approximating the first principal component) and the phosphorus concentration (approximating the second principal component). The coloured patches in Fig. 4 are 95% confidence regions for the different group means in these coordinates. Since the plot uses non-logarithmic axes, the (elliptical in log-space) confidence regions appear as deformed ellipses.

In summary the geochemical evidence highlights several activity areas, in particular discriminating between those which were likely to have been more domestic in use and those which had a more workshop-like character. ERTB 8 certainly fits into the latter group with ERTBs 5, 6 and 7 belonging to another, more domestic group. It is also possible perhaps to go further and suggest that ERTB1 had a multifunctional purpose which included craft and animal husbandry and that ERTB8 was more firmly light industrial or craft-working in character, as it shows elevated concentrations of not just The Phosphorus concentrations in ERTB8 are noticeably higher than those in ERTB1 which further suggests that this was indeed a dirty work space for at least part of its lifetime.

5. Summary and conclusions

The additional information provided by geochemical and micromorphological analysis can shed light on hitherto poorly understood or ambiguous areas of an excavation and aid in the differentiation of the use of buildings and in the interpretation of their function.

The buildings which were in use during Period 2 (c. AD 70–80 – c. AD 125–50) of the occupation of Insula IX can be divided into distinct domestic and workspace groups (be that industrial, animal-related or domestic/kitchen) on the basis of their differing elemental signatures. ERTB1 appears to have had a workspace function which may be further divided into a “street-fronting shop” and “back room” workspace based on increased elemental concentrations in the “back room”. ERTB2 is all together a cleaner environment with generally lower elemental concentrations with the exception of a possible hearth in Room 4 although this appears to have been relatively clean, and therefore probably domestic. There is significant elemental enrichment in the SW corner of ERTB2 where a “hotspot” of Copper, Zinc and Phosphorus coincides with a deposit of animal bone and charcoal. The round house ERTB3 was also probably domestic with noticeably lower phosphorus concentrations than the other buildings, but with concentrations of Copper, Zinc and Lead around the hearth. Amongst other functions it may have had a religious purpose, perhaps supported by the presence of animal and human remains, which required it to be kept clean (cf.Clarke et al., 2007).

The southern group of buildings can also be divided into domestic or workshop on the basis of elemental concentrations. ERTB8, which is closest to the street front, is the “dirtiest” building with what appears to have been a large industrial hearth. Very high Copper concentrations were recorded in this building and Phosphorus is also elevated, suggesting a workspace. ERTB7 generally appears a cleaner building than ERTB8 but it contains some elemental enrichment, specifically high Copper and Phosphorus in the vicinity of the hearth, although the samples were taken from horizons which sit below the hearth itself. In contrast ERTB6 and ERTB5 have lower elemental concentrations. ERTB6 with its high status *opus signinum* floor is noticeably cleaner than its neighbours, with comparably low concentrations of Zinc, Copper, and Phosphorus. In comparing the two groups of buildings it is striking that it is the two which are closest to the streets which have the

"dirtiest" profiles. This reinforces the interpretation that both, to a greater or lesser extent, had a retail function, contributing to commercial activity along the streets.

The use of XRF allows us to understand the use of space within these buildings to a far greater degree than would be possible using only traditional archaeological excavation, where, as we have seen (p. 00), more often than not, the presence or absence of a hearth or oven is the only feature to assist in the interpretation of the differential use of space of rooms and buildings. It is important, however, to stress that the use of geochemical data cannot be used to determine unequivocally the use of buildings or the function of hearths, rather the techniques of elemental analysis and micromorphology must be used in conjunction with excavation to contribute to the interpretation of how these buildings were used. The wider application of these techniques in urban contexts, and not necessarily just of Roman date, will enable us to build up profiles of different characterisations of their built environments.

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